Mathemat^l vol 4.

18^d

The USE of the SECTOR,

IN THE

CONSTRUCTION

OF

SOLAR ECLIPSES.

WHEREIN,

As a Proper EXAMPLE,

IS CONTAINED,

The Construction of the *GREAT ECLIPSE*,

Which will happen *May* 11. 1724.

For *London*, *Edenburgh*, *Rome*, and *Genoa*.

London: Printed for and sold by *Tho. Wright*, Mathematical Instrument Maker to His Royal Highness *GEORGE* Prince of *Wales*, at the *Orrery* and *Globe* next the *Globe Tavern* in *Fleetstreet*, 1721.

May 1722.

ADVERTISEMENT.

THE

PREFACE.

Courteous Reader,

I *Here present you with a Page or two, wherein is contained the* Construction *of the* Appearances *of* Solar Eclipses *for any given* Latitude. *I need not say any thing as to the* Excellency of this Method *beyond that of* Calculation *by means of* Parallaxes, (*which is extremely tedious and perplexed*) *that being too well known already, and especially by all those who have experienc'd the* Difference.

This Method *was first* publish'd *by Mr.* Flamstead, *and is contained in a* Piece *by him* compiled, *entitled*, The Doctrine of the Sphere; *which is annex'd to the* First Volume *of Sir* Jonas Moore's System of Mathematicks. *In the* Preface *to the said* Doctrine *of the* Sphere, *Mr.* Flamstead *tells us, that he was not the* first Inventor of this Method, *but that Sir* Christopher Wren *had known the* same Method *several Years before him. And*

likewiſe, diſcourſing with Mr. Halley, *before he went to obſerve the* Southern Conſtellations *at* St. Hellena, *the ſaid Mr.* Halley *mentioned the* Conſtruction of Eclipſes *as poſſible, but did not communicate his* Method.

It being then very probable, *that each of the before-mentioned* ingenious Perſons *might* poſſibly *have fallen* ſeperately *upon the* ſame Method, *I ſhall ſay no more as to the* firſt Invention, *but proceed to give ſome account of the* Cauſe *of my* Publication *of theſe few Pages.*

It is obvious, that Sir Jonas Moore's Syſtem *is none of the* valuableſt Pieces, (I mean as to the Matters contained therein) *and that it's* Price *is large, and not eaſie to be gotten, it being now a long time ſince it was printed. Alſo the* Firſt Part, *of the* Doctrine *of the* Sphere, *in* my Opinion, *is of no* great Value, *or at leaſt* Uſe: *For what is therein contained, is the* Explication *of the* diurnal *and* annual Phenomina, *according to the* Copernican Hypotheſis, *which may be found in other* Books *enough of a much* leſſer Price; *and by means of the* Stereographical Projection *of the* Circles *of the* Earth *upon the* Plan *of the* Ecliptick, *the Eye being in the* South Pole, *therein is ſhewn the* Manner *of* ſolving Aſtronomical Problems: *Such as finding the* Sun's right

right Aſcenſion, Declination, &c. *which is much more difficult to* conceive, *than by* ſuppoſing *the* Earth's Stability, *and the* Sun's Motion.

Therefore all that we have valuable, *is what is in the* Second Part *of the* Doctrine *of the* Sphere; *in which is not only contained* this Method *of* Conſtructing Solar Eclipſes, *but likewiſe the* Manner *of* Conſtructing *of* Stellar Eclipſes; *that is, the* Moon's Appulſes *to* fixed Stars. *You are alſo taught in the ſaid* Second Part, *how to find the* Places *of the* Luminaries *by means of* Tables *annex'd thereto, and then the* Manner *of* Calculating *the* General Phaſes of Eclipſes; *as likewiſe the* Reaſons *for the ſaid* Calculations.

But becauſe the Tables *are* erroneous, (*as Mr.* Flamſtead *himſelf owns*) *and will be quite thrown aſide, when others made upon the* Newtonian Theory *are* publiſhed, *and the* Manner *of finding the* Places *of the* Luminaries, *and the* Calculations *of the* General Phaſes of Eclipſes *are elſewhere ſhewn: Therefore the* moſt curious Part *of the ſaid* Doctrine *of the* Sphere, *is the* Conſtruction *of* Solar *and* Stellar Eclipſes.

I ſay for all the before-mentioned Reaſons, *and becauſe ſome* Perſons, skilful enough in

Aſtro-

Astronomy, *may not possibly know how to use the* Sector, *which is* absolutely necessary, *in the* Construction of Solar Eclipses, *was it, that I have* published *these* few Pages; *in* which, *I have the Vanity to believe, the* Method *is laid down something* easier *than Mr.* Flamstead *has done it.*

I wou'd have you observe, *that a* Sector proper for this Work *ought to be one of no less Length than* One Foot: *For it is impossible to do the* Business *tolerably exact with one of a lesser Length; because the* Lines *of* Sines *and* Chords, *on those that are lesser than* One Foot *in Length, cannot well be divided into lesser* Parts *than every* 30 Minutes; *whereas those on a* Foot Sector, *are divided into every* 15 Minutes, *and on them you may reasonably estimate every* 5 Minutes; *but if the* Sector *were yet larger it would be better.*

Moreover, *Since the* Construction *of* Stellar Eclipses *is very difficult and tedious, upon the account of finding the true time of the* Conjunction *of the* Moon *and a* Star; *and likewise it being a* Curiosity *not near so much taken notice of as* Solar Eclipses: (*For its* Use *in discovering the* Longitude *at* Sea *is not so great as some have imagined, the* Moon's Appulses *to* fixed Stars *being Appearances too seldom happening; or if they happen'd oftner, yet*

yet would it be difficult enough to learn Seamen *their* Conſtruction.) *Therefore I ſhall be ſilent as to this* Head, *and content my ſelf with what hereafter follows, hoping it will not be unacceptable.*

Only note, *That the Difference of* Meridians *of two Places whoſe* Latitudes *are known, may be alſo readily had from the* Conſtruction *of* Solar Eclipſes, *by obſerving the* exact Times *of the* Beginnings *or* Endings *of the ſame* Eclipſe *at both the Places.* For example; *Suppoſe the Beginning of the* Eclipſe(*in the* Great Scheme,) *at* Rome, *is* 42 Minutes *paſt* 6; *having ſet one Foot of your Compaſſes upon* 42 Minutes *paſt* 6 *in the Path of* Rome, *with the Extent of the* Semi-diameter *of the* Penumbra *make an Arc, cutting the* Line *of the* Moon's Way; *and the Point wherein it cuts it, will be about* 52 Minutes *paſt* 5 *at* London. *Whence the Difference of* Meridians *between* London *and* Rome *in time will be* 50 Minutes; *which converted into* Degrees *and Minutes, will be about* 12 Degrees 37′; *and ſuch is the Difference of* Longitude *between* London *and* Rome.

THE

THE

Uſe of the SECTOR

IN THE

Conſtruction of Solar Eclipſes.

DEFINITION I.

THE Path of a *Vertex*, is that Circle of the Earth which any Place or *Vertex* on its Superficies deſcribes, in the Space of 24 Hours, by the Earth's Diurnal Revolution. Whence the Paths of *Vertices* are Circles parallel to the Equator.

DEFIN. II.

If a Plan be conceived to touch the Moon's Orbit in that Point, wherein a Line connecting the Centers of the Earth and Sun interſects the ſaid Orbit, and ſtands at right Angles to the aforenamed Line: And if an infinite Number of right Lines be ſuppoſed to

paſs

paſs from the Center of the Sun, thro' this Plan to the Periphery of the Earth, to its Axis, as likewiſe to the Axis of the Ecliptick, and the Path of any *Vertex*; the ſaid Lines will orthographically project, the Earth's Disk, its Axis, the Axis of the Ecliptick, and the Path of the *Vertex*, on the aforeſaid Plan; and this is the Projection we are to delineate. This being preſuppoſed, it will follow;

1. That when the Sun is in ♋ ♌ ♍ ♎ ♏ ♐, the *Northern* Half of the Earth's Axis projected on the aforeſaid Plan, viewed on that Side next to the Earth, lies to the right Hand from the Axis of the Ecliptick: But if the Longitude of the Sun be in any of the Six oppoſite Sines, it lies to the left Hand from the Axis of the Ecliptick.

2. When the Sun's apparent Place happens to be either in ♈ ♉ ♊ ♋ ♌ ♍, the *North Pole* lies in the *illuminate* or viſible part of the Disk; but otherways in the *obſcure*.

3. When the Sun's Place in the Ecliptick is 90 Degrees diſtant from either Pole; that is, when the Sun is in the Equator, *the Paths of the Vertices*, or all Circles of the Earth parallel to the Equator, will be projected in right Lines upon the ſaid Plan; but if the Sun's Place be leſſer than 90 Degrees, the ſaid Paths will be projected in Ellipſes upon the ſaid Plan, whoſe conjugate Diameters will be

so much the lesser, as the Place of the Sun is lesser.

4. *The transverse Diameter of the Ellipses* representing any Path, is equal to double the right Sine of the Distance of the said *Vertex* from the *Pole*; that is, equal to twice the Co-Sine of the Latitude of the Place or *Vertex*: but the *Conjugate*, to the Difference of the right Sines of the Sum, and Difference of the Distances of the Path and Sun from the Pole; that is, equal to the Sine of the Complement of the Sun's Declination added to the Co-Latitude of the Place, less the right Sine of the Difference of the Complement of the Sun's Declination, and the Co-Latitude of the Place.

5. The transverse Diameter lies at right Angles to the Earth's Axis, and the conjugate, coincides therewith.

CHAP. I.

To represent in Plano, the Path of a Vertex in the Earth's Disk, whose Distance from the North Pole is 38°. 32′, *the Sun's Place being in* 10° 40′ 30″ of ♊ *semblable to that which will be projected on a Plan, touching the Earth's Orbit in that Point, by strait Lines produced from the Sun to the Earth.*

HAving drawn the Semicircle *Fig.* 1. HER, let it represent the Northern Half of the Earth's illuminate

Disk (becauſe the Sun is in *Gemini*) proje-ēted upon the ſaid Plan, ⊙ it's Center, the Point therein oppoſite to the Sun, H⊙R an Arc of the Eclīptick paſſing through it. Upon ⊙ raiſe ⊙E, perpendicular to the Ecliptick HR, and the Point E wherein it interſects the Limb of the Disk, will be the Pole of the Ecliptick, and ⊙E it's Axis.

Again; Make ⊙E equal to the Radius of a Line of Chords (by Chap. 3 of the Uſe of the Sector) from which taking the Chord of 23° 29′,(the conſtant Diſtance of the two Poles) ſet it off both ways from E to B and C, draw the Line BC, in which the Northern Pole of the World ſhall be found.

Make BA, equal to AC, the half of this Line, the Radius of a Line of Sines (by Chap. 3 of the Uſe of the Sector) and therein ſet off the Sine of the Sun's Diſtance from the Solſtitial Colure 19° 19′ 30″, from A to P, on the left hand of the Axis of the Ecliptick, (becauſe the Sun is in Gemini) and draw the Line ⊙P, which will be the Axis of the Earth, and P the Place of North Pole in the illuminate Hemiſphere of the Disk.

Or the Angle E⊙I, which the Axis of the Earth and Ecliptick, make with each other, may be more accurately determined by Calculation: For,

As

As Radius, ——	90° 00′ 00″	10,0000000
to the Sine of the Suns Distance from the solstitial Colure	19° 19′ 30″	9,519731
So is the Tangent of the Sun's greatest Declination to the	23° 29′ 00″	9,637956
Tangent of the Inclinat. of the Axis.	8° 10′ 54″	9,157687

Count the ſaid 8° 10′ 54″ in the Limb of the Disk from E to I, on the left hand, and draw the Line ☉I, this ſhall be the Axis; and the Point P wherein it interſects the Line BC, the Place of the Pole in the illuminate Disk.

The next thing required will be the Sun's Diſtance from the Pole; or, the Complement of his Declination, which will be found 67° 57′ 48″, this added to the Diſtance of the Vertex from the Pole 38° 32′, make 106° 29′ 48″, and the ſame 38° 32′ taken from 67° 51′ 48″, gives 29° 25′ 48″, the Meridional Diſtance of the Sun from the *Vertex*.

Make ☉E the Radius of the Disk, to be the Radius of a Line of Sines, from which take the Sine of 73° 30′ 12″, (the Complement of 106° 29′ 48″ to a Semi-circle) and ſet it off in the Axis from ☉ to 12, it there gives the Meridional Interſection of the Nocturnal Arc of the Path with the Axis.

Take

Take the Sine of 29° 25′ 48″, from the ſame Line of Sines, and ſet it off the ſame way from ⊙ to M, and it there gives the Interſection of the Diurnal Arc of the Path with the Meridian. Whence M 12 will be the conjugate Diameter of the Path, it being the Difference of the Sines of 70° 30′ 12″, and 29° 25′ 48″; that is, the Difference of the Sines of the Sum, and Difference of the Diſtances of the Path and Sun from the Pole, which will be the conjugate Diameter of any Path.

Biſect 12 M in C, and thro' it draw 6 C 6 at right Angles to the Axis of the Globe; and then taking the Sine of 38° 32′, the Diſtance of the Pole from the *Vertex*, ſet it off from C both ways to 6 and 6; then the Line 66 will be the *Tranſverſe-diameter* of the Path, and C 6 the *Semi-diameter*.

Making C 6 equal to the Radius of a Line of Sines, if from the ſame you take the right Sines of 15, 30, 45, 60, 75 Degrees and ſet them off ſeverally both ways from C in the tranſverſe Diameter, and from the Points ſo found erect Perpendiculars, a 11, a 1, a 10, a 2, &c. equal to the Coſines of the ſaid Arc's, taken from a Line of Sines, whoſe Radius ſhall be C 12, equal to CM, you will have 24 Points given, through which the Ellipſis repreſenting the Path ſhall paſs, which ſhall alſo ſhew the Place of the Vertex at every Hour of the Day.

Day. In the ſame manner may the Parts of an Hour be pricked down in the Path, in laying off the Sine of the Degrees and Minutes correſponding thereto from C towards 6, and then raiſing Perpendiculars from the Points ſo found in the Semi-tranſverſe, and ſetting off from the ſaid Semi-tranſverſe each way upon the Perpendiculars, the Sines of the Complements of the Degrees and Minutes correſponding to the aforeſaid Parts of an Hour. As for Example; To denote half an Hour paſt 11 and 12, take the Sine of 7 Degrees 30 Minutes, and lay it off on both Sides from C to b and b; then take the Co-Sine of 7 Degrees 30 Minutes, and having raiſed the Perpendiculars b½, lay off the ſaid Sine Complement from b to ½, and you will have the Points in the Periphery of the Ellipſis, for half an Hour paſt 11, and half an Hour paſt 12; and in this manner may the Path be divided into Minutes, if the Ellipſis be large enough.

Take this for another Example; Suppoſe I would repreſent upon the Plane of the Earth's Disk, the Path of *Gibraltar*, whoſe Latitude is 35 Degrees 32 Minutes North, and the Sun's Place is in 15 Degrees 45 Minutes of *Leo*,

Having, as before, drawn the Semicircle HER, for the Northern Half of the Earth's illuminate Disk, and drawn ☉E Perpendicular to RH, as alſo drawn *Fig.* 2.

drawn the Line CB, which is always equal to twice the Chord of the Sun's greatest Declination, 23 Degrees 29 Minutes; you must next make AB equal to a Radius of a Line of Sines, and then lay off from A to P, on the right Hand of the Axis of the Eclip-tick, (because the Sun is in *Leo*) the Sine of the Sun's Distance from the Solstitial Colure 45 Degrees 45 Minutes; or, the Angle E⊙I may be more nicely determined by Calculation, as was before directed, and then ⊙PI, will be the Axis of the World.

Now the Sun's Distance from the Pole; or, the Complement of his Declination is 73 Degrees 51 Minutes, which being added to the Complement of the Latitude 54 Degrees 28 Minutes, the Sum will be 128 Degrees 19 Minutes, and this taken from 180 Degrees, the remainder will be 51 Degrees 41 Minutes; also if 54 Degrees 28 Minutes, be taken from 73 Degrees 51 Minutes, the Difference will be 19 Degrees 23 Minutes.

Then if you make the Semidiameter of the Disk, the Radius of a Line of Sines, and lay off from the Center ⊙ to 12, the Sine of 51 Degrees 41 Minutes, the Point 12 in the Axis, will be the Meridional Intersection of the Nocturnal Arc of the Path with the Axis; and if again you lay off the Sine of 19 Degrees 23 Minutes from ⊙ to M, you will have the Meridional Intersection of the Diurnal Arc of the

the Path with the Axis; whence M 12 will be the conjugate Diameter of the Eliptical Path.

And if you bisect M 12 in C, and draw the Line *6* C *6* at right Angles to the Axis ⊙I, and then lay off the Sine Complement of the Latitude 54 Degrees 28 Minutes, from C to *6* on each Side the Axis, you will have the transverse Diameter of the Path; which may be drawn and divided, as before directed, for that of Figure 1.

Note, When the elevated Pole is in the obscure Hemisphere of the Earth, that the diurnal Arc, or illuminated Part of the Path, is in that Part of the Ellipsis that lies nearest to the said Pole, but otherways in the more remote; and where the Ellipsis cuts the Limb of the Disk, are the Points on it from which the Sun appears to rise, and set, *&c.* And because these Points are necessary to be found, when an Eclipse happens near Sun Rising, or Sun Setting, they may be determined in the following manner.

Lay off the Sun's Declination 22°, 2′, upon the Limb of the Disk from R to N; as also the Complement of the Latitude of 38°, 32′, from R to P; then draw the Line ⊙N, and from the Point P let fall upon the Diameter RH, the Perpendicular PQ, cutting the Line ⊙N in L. This being done, take the Extent ⊙L, between your Compasses, and lay it off upon the Axis ⊙I *Fig.* 1.

 from

from ☉ to K; then draw a Line both ways from the Point K, parallel to the tranſverſe Axis C 6 of the Path, and the ſaid Line will cut the Limb of the Disk in the Points q p of the Sun's Riſing and Setting.

Or the Arc Ip may be more accuratly determined by Calculation; for in the Triangle ☉QL, right angl'd at Q, are given the Angle QL☉, equal to the Sun's Diſtance from the Pole; and the Side Q☉ equal to the Sine of the Latitude: To find the Side OL, which is equal to the Sine Complement of the Arc Ip; the Cannon is as the Sine of the Sun's Diſtance from the Pole, is to Radius; ſo is the Sine of the Latitude, to the Sine Complement of the Arc Ip, or Iq.

CHAP. II.

HAving in the foregoing Chapter ſhewn how to draw the Path of any Vertex upon the Earth's Disk, as likewiſe to divide it, the next things neceſſary to be given, in order to conſtruct the Phaſes of a Solar Eclipſe in any given Place on the Earth's Superficies, are;

I. The apparent Time of the neareſt Approach of the Moon to the Center of the Disk; or the time of the Middle of the Eclipſe.

II. The

II. The neareſt Diſtance of the Moon's Center from the Center of the Disk in her Paſſage over it; which is equal to her Latitude at the time of the Conjunction.

III. The Semi-diameter of the Disk at the time of the Conjunction.

IV. The Moon's Semi-diameter at the ſame time.

V. The Sun's Semi-diameter.

VI. The Semi-diameter of the Penumbra.

VII. The Angle of the Moon's Way with the Ecliptick; which is equal to the Angle that the Perpendicular to the Moon's Way forms with the Axis of the Ecliptick; and if the Argument of Latitude be more than 9 Sines, or leſs than 3, the ſaid Perpendicular lies to the left Hand; if more, to the right, from the Axis of the Ecliptick.

VIII. The Hourly Motion of the Moon from the Sun at the time of the Conjunction.

Note, The Semi-diameter of the Disk, is always equal to the Difference of the Sun and Moon's Horizontal Paralaxes.

All theſe for the Solar Eclipſe of *May* 11. 1724. will be as follows.

The apparent Time of the nearest Approach of the Moon to the Center of the Disk, will be,	H. M. Afternoon. 5. 12.
The nearest Distance of the Moon's Center from the Center of the Disk,	32′ 14″
The Semi-diameter of the Disk,	61′ 38″
The Moon's Semi-diameter,	16′ 42″
The Sun's Semi-diameter,	15′ 53″
The Semi-diameter of the Penumbra,	32′ 35″
The Angle of the Moon's Way with the Ecliptick,	5° 37′
The Hourly Motion of the Moon from the Sun,	35′ 18″

These being found from Astronomical Tables and Calculations, I shall shew how to draw the Line of the Moon's Way, or Path of the Penumbra, upon the Plan of the Earth's Disk, as it falls at the time of the Conjunction of *May* 11. 1724. and the Manner of dividing the same, for *London*, *Genoa*, and *Rome*.

Fig. 1. Having drawn the Semi-circle HER of the Earth's Disk, and the Paths of *London*, *Genoa* and *Rome*, by the Directions of the last Chapter, the Sun's Place being 61° 38′ 45″, and the Latitude of *London* 51° 31′, that

oon.

14″

58″
42″
53″

35″

37′

8″

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Fig. 2.

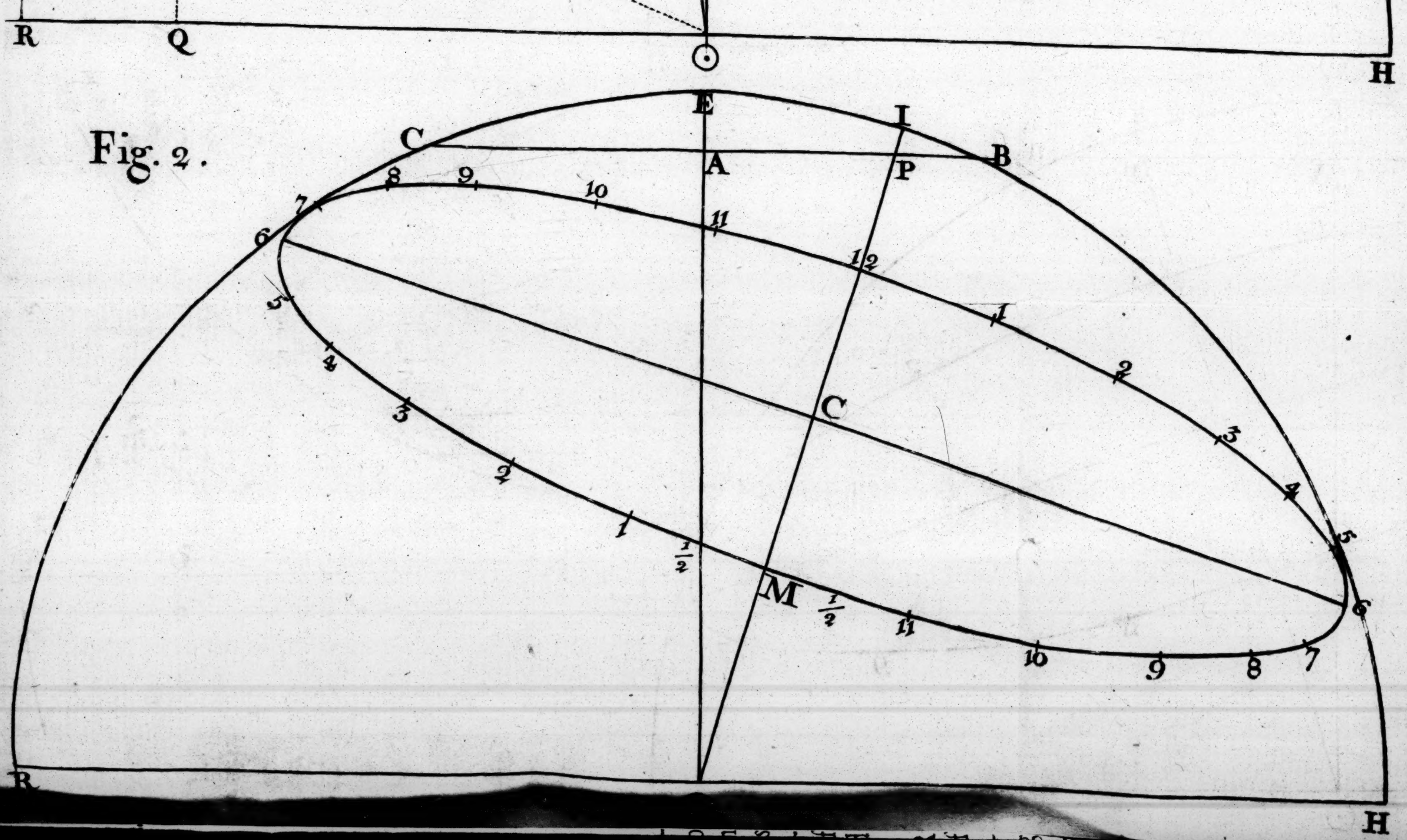
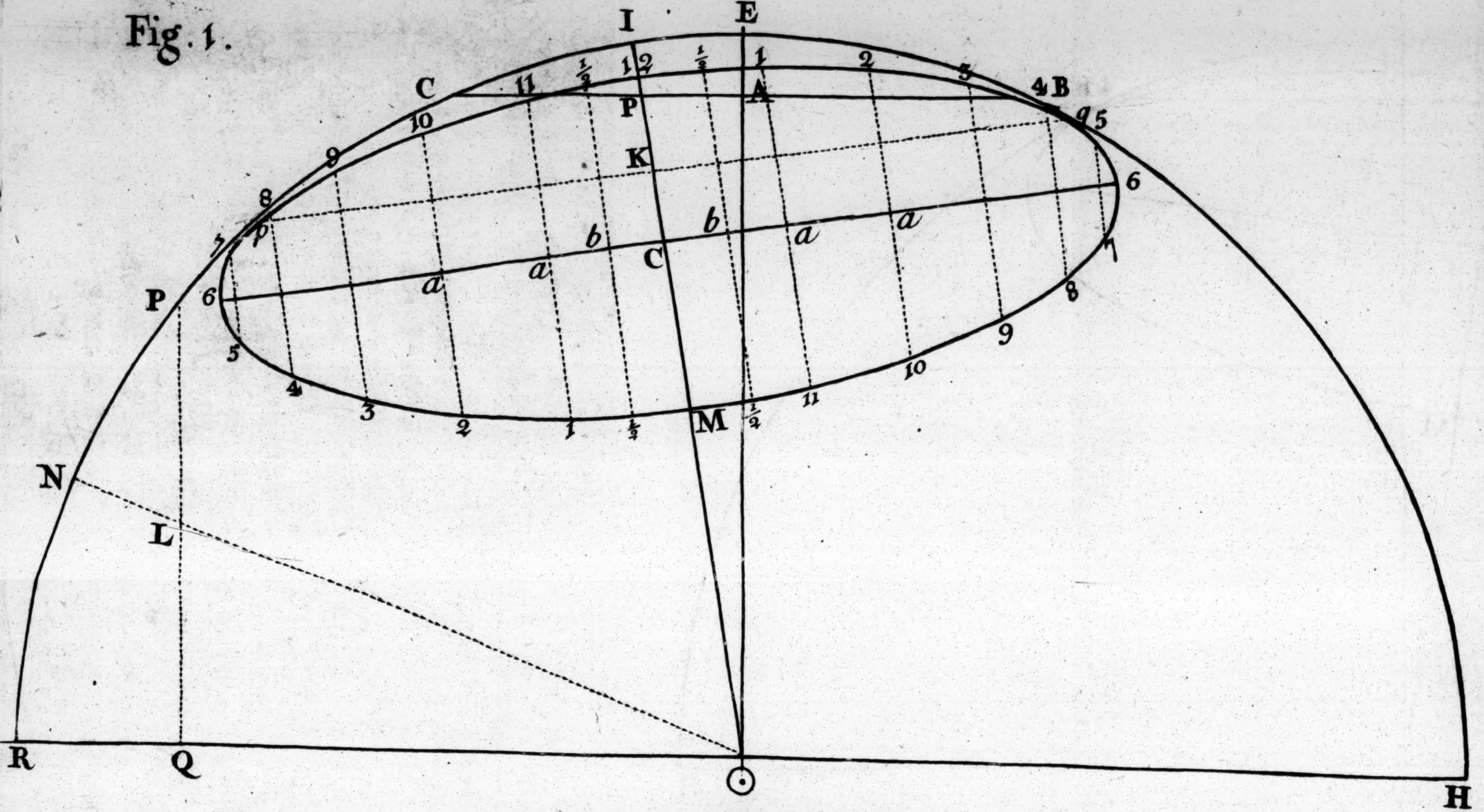


Fig. 1.



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that of *Genoa* 44° 27′, and that of *Rome* 41° 51′; you must next draw the Perpendicular to the Moon's Way; which is done thus; Take the Semi-diameter ☉H of the Disk between your Compasses, and open your Sector so, that the Distance from 60 to 60 of Chords be equal to that Extent; then taking 5° 37′ parallalwise from the Lines of Chords, (which is the Angle of the Moon's Way with the Ecliptick, or the Angle that a Perpendicular to her Way makes with the Axis E☉, of the same Ecliptick) lay it off upon the Limb of the Disk from E to F, on the right Hand of the Axis of the Ecliptick, because the Argument of Latitude is more than three Sines, and the Line ☉F being drawn, will be the Perpendicular to the Moon's Way at the time of the general Conjunction, *May* 11, 1724.

Again; Take the Semi-diameter of the Disk between your Compasses, and open the Sector so, that the Distance from $61\frac{38}{60}$, the Semi-diameter of the Disk, on each Line of Lines be equal to that Extent; then the Sector remaining thus opened, take between your Compasses the parallel Extent of $32\frac{14}{60}$, the nearest Approach of the Moon to the Center of the Disk, and lay it off from ☉ to M, upon the Perpendicular to the Moon's Way; then, if upon the Point M, a Perpendicular, as M G, be drawn both ways, this

will

will be the Line of the Moon's Way, or Path of the Penumbra.

Now to divide the ſaid Path into its proper Hours, which let be for *London*. The middle of the General Eclipſe, or the time when the Moon's Center will be at M, happens at 12 Minutes paſt 5 in the Afternoon: ſay, as 1 Hour or 60 Minutes to 35′ 18″, the hourly Motion of the Moon from the Sun; ſo is 12 Minutes the time more than 5 in the Afternoon, to 7′ 3″ the Motion from 5 a Clock to the middle.

Your Sector remaining opened to the laſt Angle it was ſet too, take the Extent from $7\frac{3}{60}$ to $7\frac{3}{60}$ on each Line of Lines, and ſetting one Foot of your Compaſſes upon M, with the other make a Point on the Moon's Way to the right Hand; and this ſhall be the Place of the Penumbra at 5 a Clock in the Afternoon at *London*; which therefore denote with the Number V.

The Hourly Motion of the Moon from the Sun is 35′ 18″, therefore take the parallel Extent of $35\frac{18}{60}$, on the Lines of Lines, between your Compaſſes, and ſetting one Foot upon V, with the other make Points on each ſide V, theſe ſhall ſhew the Place of the Moon's Center at the Hours of IV and VI; and if from theſe Points you farther ſet off the ſaid Extent in the ſaid Line, you may thereby find the Place of the Moon's Center for every

every Hour, whilst the Penumbra shall touch the Disk; and if the Space between every Hour be divided into 60 equal Parts, you shall have the Place of the Moon's Center in the Line of her Way, to every single Minute of Time.

Or, you may take the Semi-diameter of the Disk between your Compasses, and make a Scale thereof, in dividing it by means of the Sector, in the following manner: Open the Sector so, that the Distance between $61\frac{38}{60}$, the Semi-diameter of the Disk, and $61\frac{38}{60}$ on the Lines of Lines, be equal to the Semi-diameter of the Disk: This Distance lay off from A to B; then your Sector remaining thus opened, take between your Compasses successively, the parallel Distances of each Division to $61\frac{38}{60}$, and lay them off from A towards B, every 5 of which Number, and your Scale will be divided into Minutes: And by the same Method you may divide each Minute into Parts, serving for Seconds, if your Scale be long enough. Now your Scale being divided, you may make use thereof, for drawing and dividing the Path of the Penumbra, without the Sector: For $32\frac{14}{60}$ of these Parts of the Scale, gives you the nearest Distance of the Moon's Center to the Center of the Disk: Also $7\frac{3}{60}$ Parts of the said Scale, will be the Distance of the Center of the Penumbra from the Point M, at V a Clock;

and $35\frac{18}{60}$ of the Parts of the Scale, will be the Diſtance from Hour to Hour, on the Path of the Penumbra.

Now to fix Numbers upon the ſaid Path of the Penumbra, repreſenting the Hours when the Moon's Center will be at the ſaid Hours, at *Rome* and *Genoa*, we muſt have the Difference of Longitude between *London* and the ſaid two Places given; as alſo, whether they are to the *Eaſt* or *Weſt* from *London*; the Difference of Longitude between *London* and *Rome*, is 12° 37′; and between *London* and *Genoa*, is 9° 37′, they being both to the *Eaſt* from *London*. Each of theſe being reduced to Time, the former will be 50 Minutes, and the latter 38 Minutes, wherefore 5 a Clock for *Rome* on the Moon's Way, muſt be at 10′ paſt IV, for *London*; and 6 a Clock at 10 Minutes paſt V, *&c.* underſtand the ſame for other Hours and Minutes. I have noted the Hours for *Rome* under the Line of the Moon's Way, with *Roman* Characters. Again, 5 a Clock on the Moon's Way for *Genoa*, muſt be ſet at 22 Minutes paſt 5 for *London*; and 6 a Clock, at 22 Minutes paſt 6, *&c.* I have noted the Hours for *Genoa* with ſmall Figures over the Line of the Moon's Way.

Note, 10 Minutes, and 22, are each of them the Complement of 50 Minutes, and 38 Minutes to 60 Minutes.

CHAP.

CHAP. III.

To determine the apparent Time of the beginning, or end of a Solar Eclipse, the Time when the Sun shall be eclipsed to any possible Number of Digits, the Inclination of the Cusps of the Eclipse, and the Time of the visible Conjunction of the Luminaries, in any given Latitude.

THE Paths of *London*, *Rome* and *Genoa*; as also the Path of the Penumbra being drawn and divided, as directed in the two last Chapters for the Great Eclipse of 1724, which will be a very proper Example for sufficiently explaining this Method, take between your Compasses the Semi-diameter of the Penumbra $32\frac{35}{60}$, from the Lines of Lines on the Sector, it being first opened to the Semi-diameter of the Disk $61\frac{33}{60}$; or you may take it from your Scale, which being done, carry one Foot of your Compasses along the Line of the Moon's Way, from the right hand to the left; wherein find such a Point, that if the said Foot be set, the other Foot shall cut the same Hour or Minute, in the Path of the Vertex of any given Place; then the Points in the Paths upon which either of the Feet of your Compasses stand, will shew the Time of the Beginning of the Eclipse at that Place.

For Example; If you carry the Semi-diameter of the Disk along the Line of the Moon's Way, you will find that one Foot of the Compasses being set at *a*, on the Moon's Way, which is 41 Minutes past 5 in the Afternoon for *London*, the other Foot will fall on the Point b on the Path of *London*, which is likewise 41 Minutes past 5 in the Afternoon; wherefore the Beginning of the Eclipse at *London*, will be at 41 Minutes past 5 in the Afternoon.

Again; If you carry still on the Foot of your Compasses, they remaining yet opened, to the Semi-diameter of the Disk, and find another Point on the Moon's Way, whereon if you fix one Point of your Compasses, the other shall cut the Path of the Vertex at the same Hour or Minute, which this stands upon in the Line of the Moon's Way; the Points whereon your Compasses stand in either Path, shall shew the Minute the Eclipse ends.

For Example; One Foot of the Compasses being set to g in the Path of the Vertex, which is 29 Minutes past 7 in the Afternoon, the other Foot will fall upon the Line of the Moon's Way at the same Hour and Minute, *viz.* 29 Minutes past 7; therefore the Eclipse ends at *London*, 29 Minutes past 7; but take notice, that the Line of the Moon's Way should be continued further out beyond 7 a Clock, that so the Point of the Compasses

may

may fall upon the proper Minute; to wit, 29.

Moreover; If one ſide of a Square be apply'd to the Ecliptick HR, and ſo moved backwards or forwards, until the other ſide of the ſaid Square cuts the ſame Hour or Minute in the Path of the Vertex, and Line of the Moons Way; this ſame Hour or Minute, will be the time of the viſible Conjunction of the Luminaries at the given Place.

For Example; When the perpendicular ſide of the Square cuts the Path of the Moon's Way at e, which is 37 Minutes paſt 6, the ſaid ſide will likewiſe cut the Path of the Vertex for *London* at c, which is 37 Minutes paſt 6; therefore the Time of the viſible Conjunction of the Luminaries at *London* will be 37 Minutes after 6.

Draw the Line ab, as alſo the Line ☉b, this ſhall repreſent the vertical Circle, and the Angle ☉ba, will be the Angle that the vertical Circle makes with the Line connecting the Centers of the Sun and Moon, at the Beginning of the Eclipſe at *London*.

Draw the Line gm; to wit, joyn the Points in the Path of the Vertex, and the Path of the Moon's Way, which ſhews the End of the Eclipſe at *London*; and the Line ☉g, then the Angle ☉gm, will be that which the vertical Circle forms with the Line joyning the Centers of the Luminaries.

Take the Semi-diameter of the Sun, *viz.* $15\frac{53}{60}$ between your Compaſſes, either from

your Sector, opened as before directed, to the Semi-diameter of the Disk, or from your Scale, and with that upon the Center c (to wit, the Minute in the Path of *London*, whereat the time of the visible Conjunction happens) describe a Circle; this Circle shall represent the Sun.

Again; Take the Moon's Semi-diameter $16\frac{41}{60}$ from your Sector, (remaining opened as before) or your Scale upon the Center e; (to wit, the Minute in the Path of the Moon's Way, whereat the true Conjunction happens at *London*) describe another Circle. This shall cut off from the former Circle, so much as the Sun will be eclipsed, at the Time of the visible Conjunction.

From ☉ draw the Line ☉*cv*: This shall represent the vertical Circle, and *v* the vertical Point in the Sun's Limb, whereby the Position of the Cusps of the Eclipse, in respect of the Perpendicular passing thro' the Sun's Center, are plainly and easily had.

Produce dc till it intersect the Moon's Limb in p, then shall pq be the part of the Sun's Diameter eclipsed, at the time of the greatest Obscuration at *London*: And if the Sun's Diameter be divided into 12 equal Parts, or Digits, you will find pq to be $11\frac{66}{100}$ of those Parts or Digits.

Whence

Whence at *London*,

	H. M. Aftern.
The beginning of the Eclipse, *May* 11. 1724. at	05 41
The visible Conjunction of the Luminaries,	06 37 Dig. then $11\frac{66}{100}$
The End,	07 29

	H. M. Aftern.
After the same manner, the beginning of the Eclipse at *Genoa* will be,	06 27
Visible Conjunction, or middle of the Eclipse,	07 20

The Sun will there Set eclips'd, and the Eclipse will be Total.

	H. M. Afternoon.
And the beginning of the Eclipse at *Rome* is,	06 42.

The visible Conjunction, or middle, will there be when the Sun is Set, and consequently also the End.

I have, as you see in the Figure, also drawn a fourth Path for *Edenburgh*, whose Latitude is 55° 56′, and Longitude, about 3 Degrees to the *West* from *London*. Wherefore for each Hour in the Moon's Way for *London*, you must account 12 Minutes more for the same Hour at *Edenburgh*: That is, *For Example*; 5 a Clock on the Line of the Moon's Way for *Edenburgh*, must stand at 12 Minutes past 5

at *London*. Understand the same for other Hours, *&c.*

And by proceeding according to the Directions before given, you will find,

	At *Edenburgh*,	H. M. Aftern.
The beginning of the Eclipse at,		05 22
The middle,		06 20 Dig. then 11.
The end,		07 14

Note, The Path of the Moon's Way ought to be continued out further to the left hand, in order to determine the time of the End of the Eclipse at *Edenburgh*.

If you have a mind to know at what time any possible Number of Digits, or Minutes shall be eclipsed at any Place in the Sun's antecedent, or consequent Limb; divide the Sun's Diameter into Digits, or Minutes; and cut off the Parts required to be eclipsed from the Semi-diameter of the Penumbra; then take the remaining part of it between your Compasses, and carrying it along the Line of the Moon's Way, find the first Point in it, in which placing one Foot, the other will cut the same Hour in the Path of the Place that the fixed Foot stands upon; then the Hour and Minute in either Path upon which the Feet of your Compasses stand, will be the Time of that Obscuration.

As

As for Example; Suppose it was required to find at what time 6 Digits or ½ of the Sun's Diametet shall be eclipsed in his antecedent Limb at *London*. Cut off ½ of the Sun's Semi-diameter, from the Semi-diameter of the Penumbra, and carrying the Remainder, as directed, you will find, that if one Point of your Compasses be set at 6 Hours 9 Minutes in the Afternoon, on the Path of the Moon's Way, the other Point will also fall upon the same Hour and Minute in the Path of *London*; and therefore the Time when the Sun's antecedent Limb at *London* will be half eclipsed, will be at 9 Minutes past 6; and when its consequent Limb will be half eclipsed, will be at 5 Minutes past 7.

Fig. 2. Now to determine the Position of the Cusps of the the Eclipse; *For Example*, at *London*: Draw a Circle ADBE, representing the Sun's Body, and the right Line ACB, representing his vertical Diameter. This being done, lay off the Angle ☉ba upon the Sun's Limb from A to D, draw the Diameter ECD, and the Point D will be the first Point of the Sun's Limb obscured by the Moon at the Beginning of the Eclipse.

Fig. 3. Again; To determine the Position and Appearance of the Eclipse at the Time of the middle, or greatest Obscuration; take the Sun's Semi-diameter between your Compasses, and upon the Point C, describe

describe a Circle; then draw the vertical Diameter ACB, and make the Angle ACD equal to the Angle v c p, and draw the Diameter DCF. This being done, take the Moon's Semi-diameter between your Compasses, and having lay'd off from the Center C to E, the Distance c e in the first Figure; upon the Point E, as a Center, describe an Arc cutting the Sun's Limb and the Position, and Appearance of the Eclipse at the Time of the greatest Obscuration, or the Middle, at *London* will be as you see in the Figure,

Lastly; To determine the Position of the End of the Eclipse. Draw a Circle, (as in the *4th* Figure) and cross it with the vertical Diameter ACB; then make the Angle ACE equal to the Angle ⊙ g m, and draw the Diameter ED; then will the Point E on the Limb of the Sun, be that which is last obscured, or whereat the Eclipse ends.

If you have a mind to find the Continuation of total Darkness at any Place where the Sun will be totally eclipsed, cut off the Semi-diameter of the Sun, from the Semi-diameter of the Penumbra, and taking the Remainder between your Compasses, carry it along the Line of the Moon's Way, and find the first Point in it; on which placing one Foot, the other will cut the same Hour in the Path of the Place; which Hour note down. Again, Carrying on further the same Extent of your Compasses, find

find two Points on the Paths of the Vertex and Moon's Way, which ſhall ſhew the ſame Hour and Minute on them both. This time alſo note down; then ſubſtract the time before found from this time, and the Difference will be the time of Continuance of total Darkneſs.

CHAP. IV.

To determine the Time that the Penumbra is paſſing over the Disk; what Place of the Earth the Penumbra firſt touches; or in what Place the ſupreme Point of the Sun's vertical Diameter will at his Riſing appear eclipſed: As alſo the manner of tracing the Paſſage of the Moon's Shadow over the Disk.

NOW to determine the time the Penumbra is paſſing over the Disk, you muſt conſult *Fig.* 5. where EL is the Path of the Penumbra ſuppoſed to be drawn and divided, as has been already directed: Then if you deſcribe with one Foot of your Compaſſes upon the Center S, with a Radius equal to the Sum of the Semidiameters of the Disk and Penumbra, the Arc's FF, FF, they will cut the Path of the Penumbra in the Points E and L, and then the Hours and Minutes of the ſaid Path included between the ſaid Points, will be the time that the Penumbra is paſſing over the Disk, which will be found 5 Hours

2 Minutes. Moreover, the Point L ſhews the time of the Beginning of the General Eclipſe, and the Point E the End; the former will be at 2 Hours 41 Minutes, and the latter at 7 Hours 43 Minutes; theſe may alſo be found by Calculation, by means of the right lined right angled Triangles SME, SML, ES=SL, and SM, being given.

Before we can find the next thing propoſed, *viz.* the Place of the Earth the Penumbra firſt touches, we muſt find at what Place the Sun in a given time is vertical. Find the Sun's Place in the Ecliptick at the given time, and then its Declination will be the Latitude of the ſought Place; and its Longitude from that Place from which the time is reckoned, will be had in converting the time from the Meridian, into Degrees and Minutes, of the Equinoctial: *As for Example*; The Longitude of a Place in whoſe Vertex the Sun is at 7 a Clock in the Morning at *London*, will be had by ſubſtracting 7 from 12, and multiplying the Remainder 5 by 15, *viz.* 75° Degrees. Therefore that Place will be 75° *Eaſtward* from *London*.

This being found, we proceed to determine the Place of the Earth C, where the Penumbra firſt touches the Disk. Draw PC thro' P, the Pole to C, where the Penumbra firſt touches the Disk; then in the right lined right angled Triangle SLM, you may find the Angle MSL,

MSL, and confequently the Angle BSL, becaufe MSB is given. Again; In the right angled fpherical Triangle BPC on the Superficies of the Earth, are given BP, the Sun's Declination, and the Arc BC, which is the Meafure of the Angle BSL, where you may find the Arc PC, the Complement of the Latitude of the Place fought; as alfo the Angle BPC, whofe Complement CPS to two right Angles, will be the Diftance of the Meridians of the Place C, and that Place in which the Sun is vertical; and fince this Place is known, the Place C will likewife be known.

Again; To find the Place of the Earth H, at which the Center of the Penumbra fhall be at a given time, you will by the Hourly Motion of the Moon, have the Length MH; and then in the right angled Triangle SMH, the Side SH may be found, and the Angle HSM, (becaufe MS is alfo given) and confequently the Angle HSB, fince MSB is given. But SH is the Sine of the Arc of a vertical Circle paffing thro' the Vertex of the Place H and the Sun, the Semi-diameter of the Disk being Radius; whence if you fay, as the Semi-diameter of the Disk is to SH, fo is radius to another, you will have the Sine of an Arc, that will be the Sun's Diftance from the Vertex H. Now in the oblique fpherical Triangle on the Superficies of the Earth SHP, are given SP, the Sun's Diftance from the Pole of the World,

SH the Sun's Diſtance from the Vertex, and the Angle HSP: To find the Side HP, the Complement of the Latitude of the ſought Place; and the Angle HPS, which is the Difference of Meridians of the Place H, and that Place whereat the Sun is vertical; but the Difference of the Meridians of that Place whereat the Sun is vertical, and that from which the time is computed, is given; whence the Place H will be known. And if, according to this Method, ſeveral Places on the Earth's Superficies are found, and they are joyned by Lines, you will have the Path of the Center of the Penumbra, over the Superficies of the Earth.

In like Manner; If you have a mind to determine the Breadth of the Moon's Shadow, raiſe a Perpendicular HG upon the Point H, equal to the Difference of the Sun and Moon's apparent Semi-diameters; then in the right angled Triangle SQG, are given SQ and GQ; whence GS may be found, and the Angle GSQ, and ſo the Angle GSB. But SG is the Sine of the Diſtance of the Place G, thro' which the Extremity of the Shadow paſſes, when the Center of it is at the Place H; therefore the Latitude and Longitude of the Place G may be found by means of the ſpherical Triangle SPG, exactly in the ſame manner as before, for the Latitude and Longitude of the Place H. And in the ſame manner may the Latitude

Latitude and Longitude of the Place R, be determined on the other Side the Path of the Penumbra: And if the Latitudes and Longitudes be thus found on both Sides the Path of the Penumbra, and they are joyned by Lines, the ſaid Lines will limit the Breadth of the Moon's Shadow; and all Places contained within thoſe Limits, will be involved in total Darkneſs at the time of the Eclipſe.

Note, After the ſame way may the Breadth of the Penumbra be determined.

The Cannon for finding the Side PC, of the right angled ſpherical Triangle PBC, is as Radius is to the Sine Complement of either of the given Sides PB, BC; ſo is the Sine Complement of the other Side, to the Sine Complement of the ſought Side PC.

And the Cannon for finding the Side PS of the oblique ſpherical Triangle PHS, by having the Sides PS, and HS, and the Angle PSH included between them given, is as the Cube of Radius is to the Rectangle under the Sines of the given Sides PH, SH; ſo is the Square of the Sine of half the given Angle PSH, to half the Difference of the verſed Sines of the ſought Side PH, and the Arc of Difference between the given Sides; which half Difference doubled, and added to the verſed Sine of the Difference of the two given

ven Sides, gives the versed Sine of the Side sought.

In the working this Case, it will be proper to use *Sherwin*'s Tables, because there is requir'd natural Sines, and versed Sines, standing against the artificial ones.

But this Case may likewise be solved at two Operations, by supposing a Perpendicular to be let fall, without the help of natural Tables: For,

First, If both the given Sides are equal, then it will hold, as Radius is to the Sine of either of the Sides; so is the Sine of half the given Angle, to the Sine of half the Side sought.

Secondly, If one of the given Sides be a Quadrant; this, by continuing out the other given Side to a Quadrant, will become a Case of right angled spherical Triangles; in which, besides the right Angle, instead of the quadrantal Side, there will be one Leg given, and its adjacent Angle, to find the other Angle, by the fourth Case of right angled spherical Triangles: Also, if the Angle given was 90 Degrees, it would be a Case of right angled spherical Triangles; in which, besides the right Angle, there would be both the Sides given, to find the Hypothenuse.

Thirdly,

Thirdly, If both the given Sides are leſſer than Quadrants, it will hold, as Radius is to the Coſine of the given Angle; ſo is the Tangent of the leſſer given Side, to the Tangent of a South Arc; then if the given Angle be leſſer than 90 Degrees, ſubſtract the ſaid fourth Arc from the other given Side; but if it be more, from the other Sides Complement to 180 Degrees, and the Remainder is called the reſidual Arc; then ſay again, as the Coſine of the fourth Arc, to the Coſine of the reſidual Arc; ſo is the Coſine of the leſſer given Side, to the Coſine of the Side ſought.

Now the Side ſought may be greater than a Quadrant, and ſo be doubtful: In order to ſolve which; when the given Sides are both either greater or leſſer than Quadrants, and the Angle given acute, the Side ſought will be leſſer than a Quadrant.

But when the given Sides are one greater and the other leſſer than a Quadrant, and the Angle comprehended between them is obtuſe, the Side ſought will be greater than a Quadrant.

F I N I S.

Alfo, if both the given Sides are leffer
than Quadrants, it will hold as, The Radius is
to the Cofine of the given Angle, fo is the
Tangent of the leffer Side, to the Tan-
gent of a fourth Arc; Then if the given Angle
be leffer than 90 Degrees, fubftract the faid
fourth Arc from the other given Side; but if
it be more, from the other Side's Comple-
ment to 180 Degrees, and the Remainder is
called the refidual Arc: then fay again, as
the Cofine of the fourth Arc, to the Cofine
of the refidual Arc; fo is the Cofine of the
leffer given Side, to the Cofine of the Side
fought.

Now the Side fought may be greater than
a Quadrant, and to be doubtful: In order to
folve which; when the given Sides are both
either greater or leffer than Quadrants, and
the Angle given acute, the Side fought will
be leffer than a Quadrant.

But when the given Sides are one greater
and the other leffer than a Quadrant, and the
Angle comprehended between them is
acute, the Side fought will be greater than
a Quadrant.

F I N I S.

Zdly, If both the given Sides are lesser than Quadrants; then say, as Radius is to the Co-sine of the given Angle; so is the Tangent of the lesser given Side, to the Tangent of a Fourth Arc; then if the given Angle is lesser than 90 Degrees, subtract the said fourth Arc from the other given Side; but if it be more, from the other Sides Complement to 180 Degrees, and the Remainder is called the second Arc: then say again, as the Cosine of the fourth Arc, to the Cosine of the second Arc; so is the Cosine of the lesser given Side, to the Cosine of the Side sought.

Now the Side sought may be greater than a Quadrant, and so be doubtful: In order to know which; when the given Sides are both either greater or lesser than a Quadrant, and the Angle given acute, the Side sought will be lesser than a Quadrant.

But when the given Sides are one greater and the other lesser than a Quadrant, and the Angle comprehended between them obtuse, the Side sought will be greater than a Quadrant.

F I N I S.

Fig. 1.

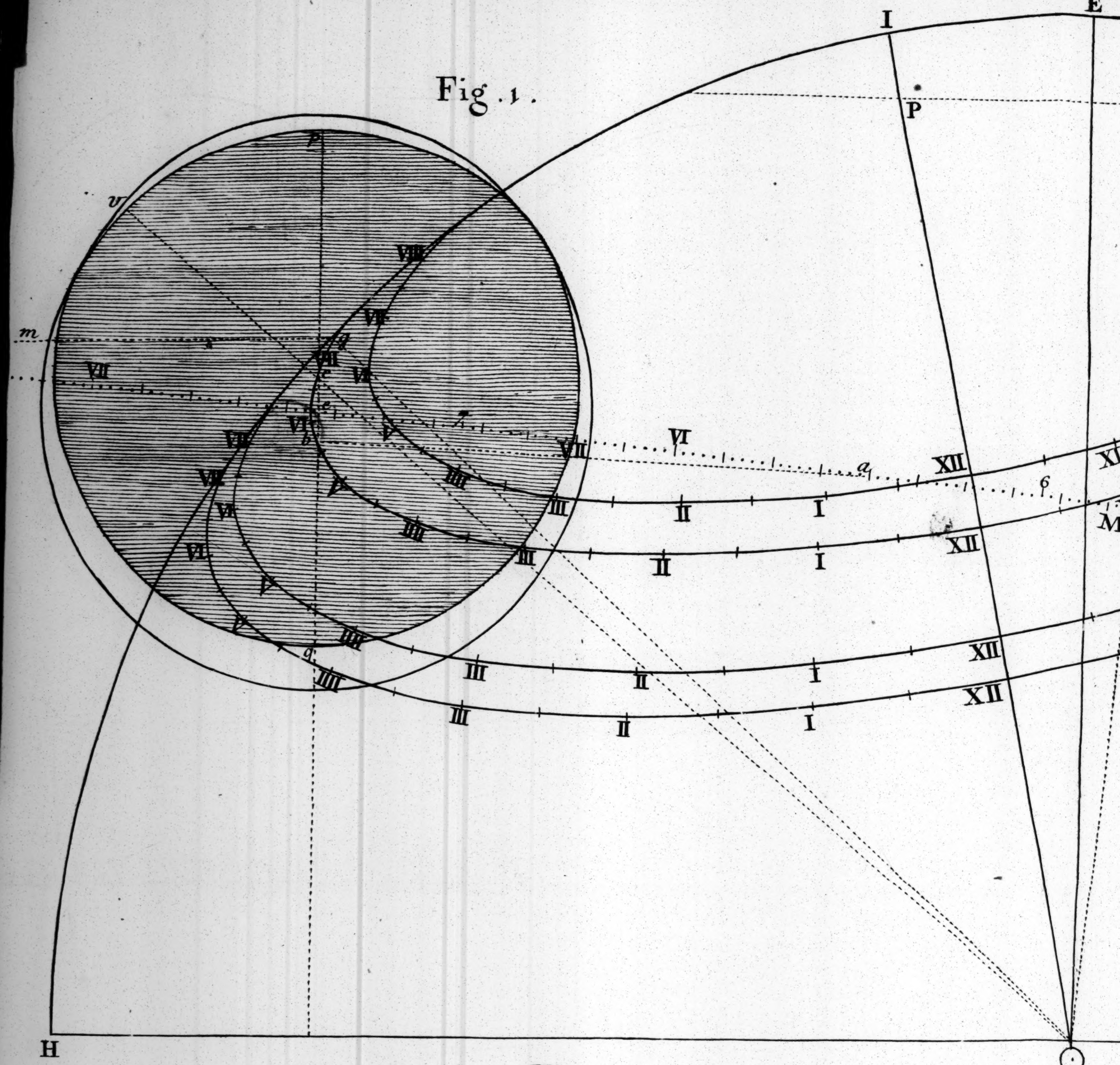
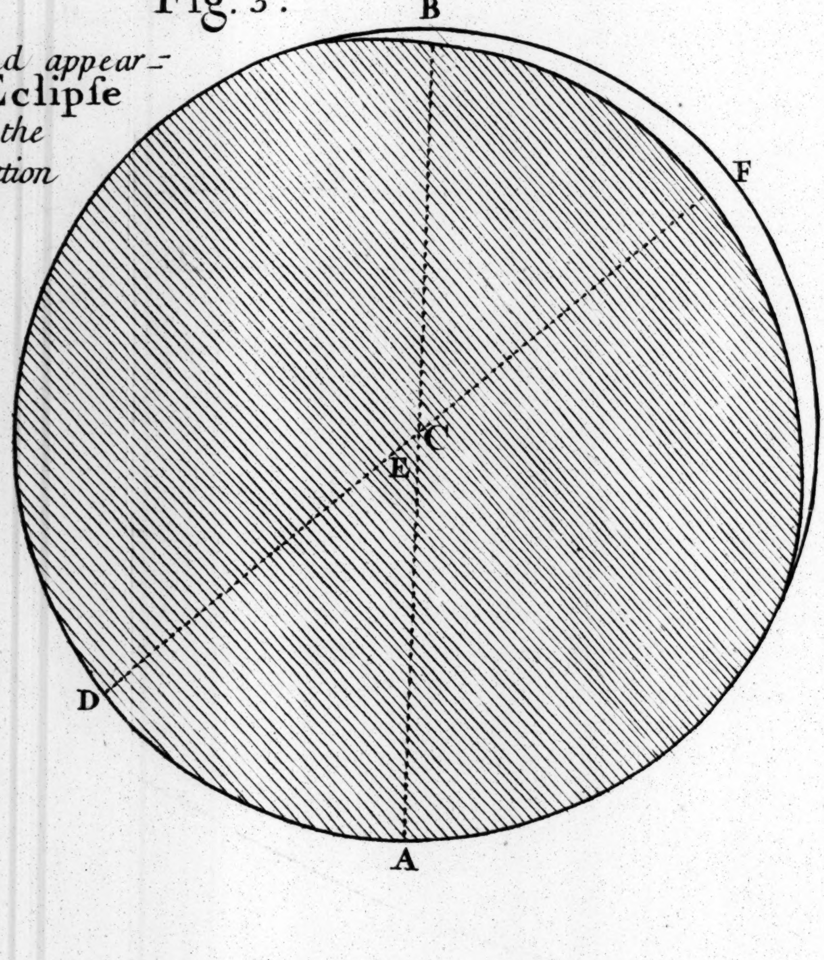
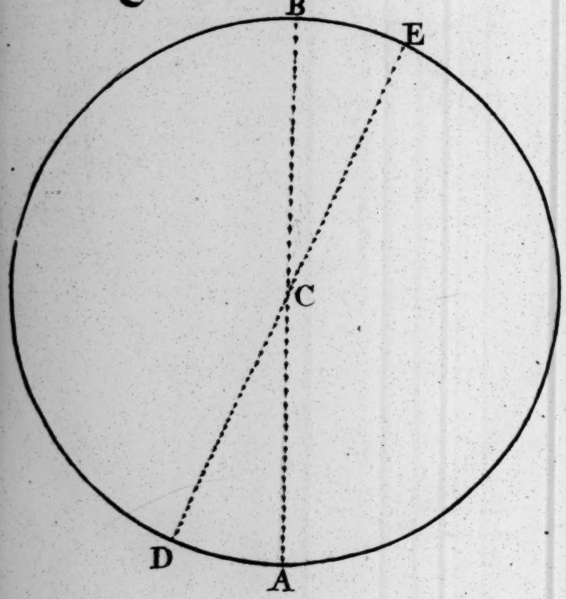


Fig. 3.



The Position and appear=
=ance of the Eclipse
at the time of the
greatest Obscuration
at London

Fig. 2.



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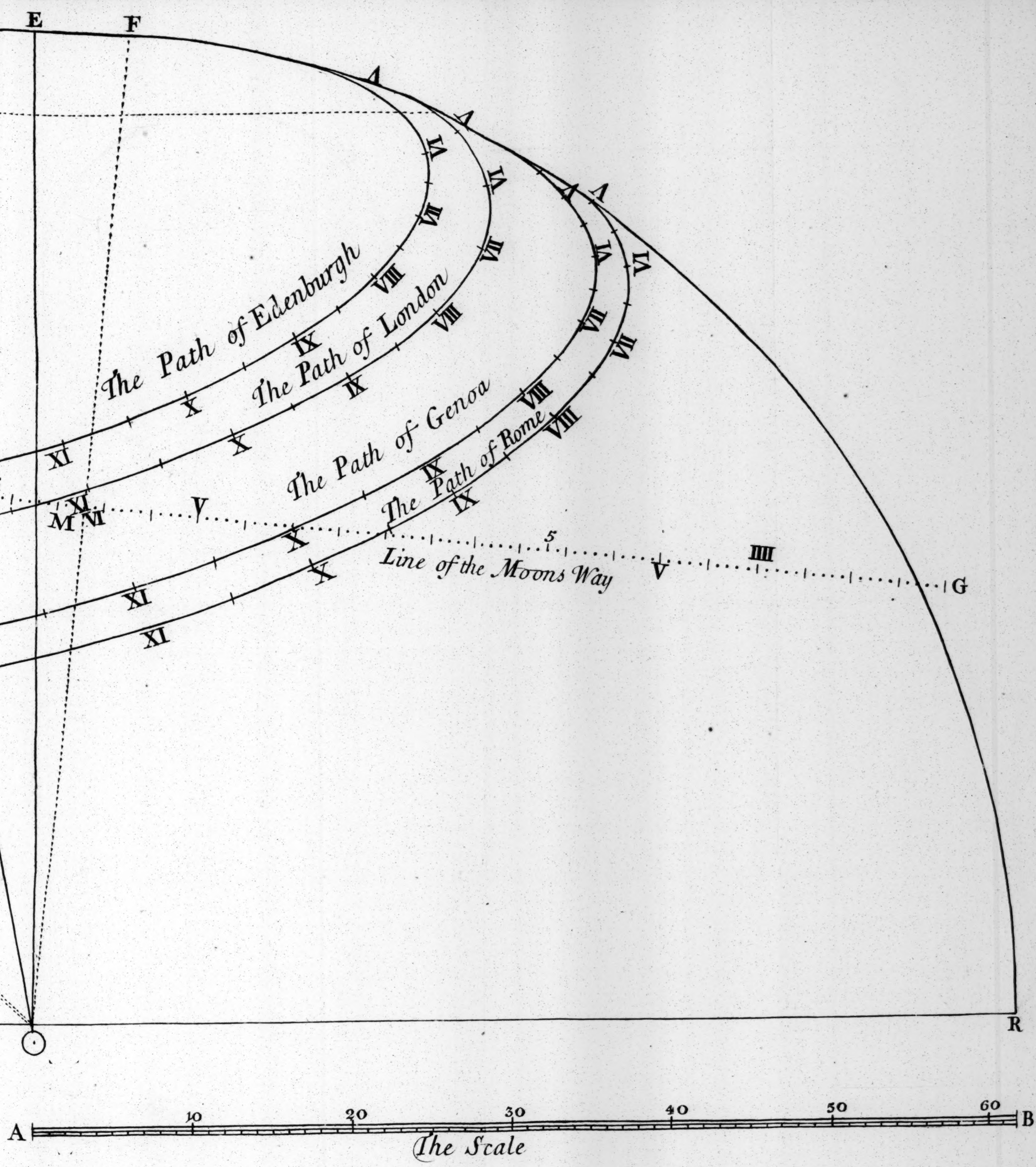

E
F
The Path of Edenburgh
The Path of London
The Path of Genoa
The Path of Rome
Line of the Moons Way
M
G
R
A
B
10
20
30
40
50
60
The Scale

Fig. 4.

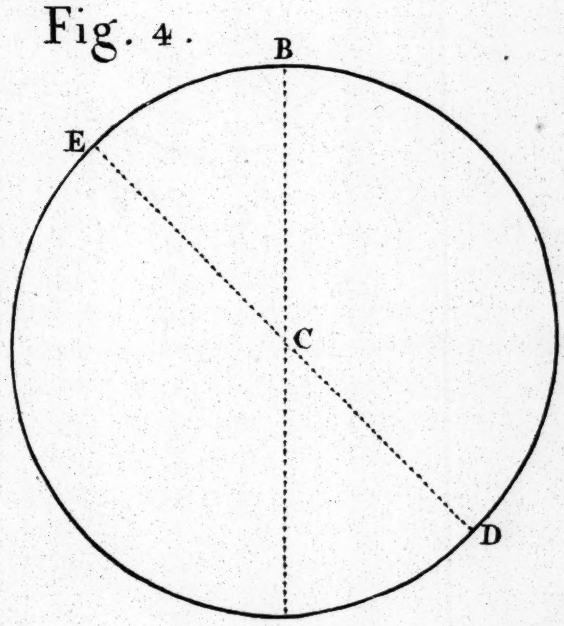
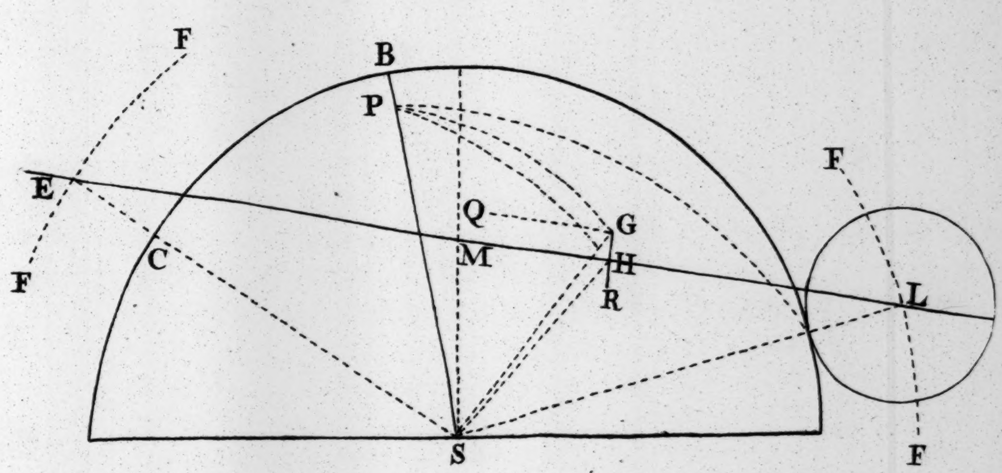

B
E
C
D
A

Fig. 5.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